Effects of Spatial Disorientation on Cognitive Functions

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Summary: Spatial Disorientation is well known by fliers but, generally it is too difficult to overcome. Even if it is managed, a pilot might still be at risk of serious dangers. After simulating Spatial Disorientation in laboratory conditions, any impairment of cognitive functions of the pilots was examined in order to find out whether Spatial Disorientation has any negative effect on cognitive functions. Two groups of, totally 82 pilot candidates who were to have Spatial Disorientation training in Turkish Aeromedical Center, were given WAIS-DSST (Wechler Adult's Intelligent Scale - Digit Symbol Substitution Test) or LCT (Letter Cancellation Test) to measure the differences of attention and percept after Spatial Disorientation. Both test results show that Spatial Disorientation causes impairment of cognitive functions.

Introduction: SD is a topic of interest, which has been discussed and investigated largely for years. Many articles have been written regarding the role of SD in mishaps. It has been shown that SD mishaps are the most fatal mishaps in military and commercial aviation.
Since this subject takes great importance lots of methods have been developed as a countermeasure and still a number of studies are being held to overcome this threat.
SD is defined as a subset of LSA, although some authors have offered new view and an operational definition for SD the majority supports traditional view. According to that, if a pilot is spatially disoriented then the one also lost situational awareness whereas a pilot can lose situational awareness without being disoriented.
In the light of above-mentioned definitions one can think when a disoriented pilot reestablishes his orientation then he can regain his situational awareness (in the lack of other LSA causes). But is this conclusion completely true? In other words Can SD have any postponed effect on SA or on cognitive functions even after establishing orientation
In our study we sought for any residual effects on pilots performance in cognitive tests after SD training.

Methods: The study was held in Turkish Aeromedical Center. Spatial Disorientation training Device "Gyrolab" was used. Gyrolab is an ETC (USA) made SD trainer offering both computer and manual controlled motion in four axis; yaw and roll (360^0), pitch (90^0 up and down), and planetary (up to $2.2G_z$ or 28RPM).
82 male pilot candidates at a mean age of 22.2 (22-24) were involved in the study. They had been sent to our center for initial physiological training at the beginning of Undergraduate Pilot Training. Before having the SD training they were given a lecture about SD and common illusions. Each pilot was given a pencil and a paper test at the end of the SD training, and a control test at rest period. Half of the trainees had their control tests two days before SD training and the other two days after training. Before having test each individual was shortly informed about the test.
Two pencil and paper tests were used: Letter Cancellation Test (LCT) and Wechler Adults Intelligent Scale Digit Symbol Substitution Test (DSST).
In LCT, there is one sheet of b, p, d, q letters (totally 546) in random order, subjects were asked to cancel all "b" s on their sheet as soon as possible in 120 seconds. At the end of the test correctly cancelled "b" s were counted as the test score.
In DSST there are 9 symbols as substitutes of 9 digits at the top of the sheet. The subjects were asked to substitute 100 digits, written in random order with the appropriate symbols as soon as possible in 120 seconds. At the end of the test correctly substituted digits were counted as the test score, same statistical analysis were made for both of the tests.

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Analysis were made regarding the whole group of subjects and with two subgroups according to the time of control tests before or after post SD training test distinctively, this was made to investigate the learning effect on test results.
The whole group's results were analysed using "Paired Samples Test" and subgroups were analysed using Wilcoxon test.
Mean test scores of the two subgroups were compared by using Mann Whitney U Test. The correlation between post SD test scores and control (rest time) test scores were analysed by using Pearson's correlation.

Results: In the DSST group of 40 subjects there is a decrease of 11.2 in the mean post SD test scores with respect to control (rest time) tests (89.7 versus 78.57). Test results are shown in Table I.
Either the whole group's or the subgroup's test analysis gave statistically significant results.

Table-I

DSST	Control		After SD		p
	Mean	sd	Mean	sd	
Total n=40	89,73	9,27	78,57	10,96	0,0001***
Grup 1 n=20	89,85	10,08	76,45	9,53	0,0001*
Grup 2 n=20	89,6	8,64	80,7	12,1	0,004*
P**	0.82		0.26		

**Wilcoxon test*
*** Comparison of two groups with Mann Whitney U test.*
**** Paired Samples t Test.*
The correlation between the rest time scores and post SD scores was not so strong (R:0.446) but, statistically significant (p:0.004) when analysed by using Pearson's correlation.

In the LCT group of 42 subjects, there is a decrease of 24.4 in the mean post SD scores with respect to control (rest time) tests. LCT test results are shown in Table II.
Either the whole group's or the subgroup's test analysis gave statistically significant results.

Table-II

LCT	Control		After SD		p
	Mean	sd	Mean	sd	
Total n=42	504.38	49.96	479.98	52.72	0.0001***
Grup 1 n=20	519.15	31.16	486.5	47.35	0.001*
Grup 2 n=22	490.95	59.98	474.04	57.62	0.008*
P**	0.38		0.43		

**Wilcoxon test*
*** Comparison of two groups with Mann Whitney U test.*
**** Paired Samples t Test.*
There was also a strong correlation between the rest time scores and post SD scores (R:0.793) and it was statistically significant when analysed with Pearson's correlation.

Discussion: SD is becoming a bigger problem day by day because technological advances in the high performance aircraft's new devices or new designs is going ahead of the advances in SD countermeasures. SD mishaps take great concern proportionally with the size of threat. Researches are made to avoid SD or SD related mishaps. And countermeasures are effective only in some extent. But SD is not the only threat for a pilot. Avoiding or overcoming SD is not the all case. The pilot should continue and complete flight duties. At this point he has to use his acquired skills, his knowledge, short and long term memory, information processing and all cognitive functions. Any impairment of these functions could also cause big threats, which we generally name as LSA.
As a definition SA is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future. This term comprises not only tactical arena, navigation, weather, communications, aircraft capability, but spatial orientation as well. It is clearly seen that SD will cause LSA at the same time but after orientation recovered there are still several task elements to be maintained in order to regain or maintain SA.

SD is a complex confliction causing the pilot to suspect the aircraft's flight parameters for some time. In this time it is possible that he can not completely concentrate on the flight, or the related task elements. In this case the problem would not be SD, but SA could be compromised in some extent.
In our study we aimed to see if there is any residual effect on cognitive functions after SD. For this goal SD was recreated in laboratory conditions then we used two simple tests.
Our test results suggest that under laboratory conditions, pilots had difficulty in managing the given simple tasks. They were more successful when they had the tests at rest time period.
Of course SD recreated in laboratory is not exactly the same with the real flight conditions. Therefore we don't know the exact effects occurring in flight. On the other hand, the tests that we used were simple and easy to apply but the results showed some training effect.
The time needed to totally recover from adverse residual effects of SD, the role of some individual factors such as flight hours, flight years, instrument flight or age and differences related with disorientation type was beyond the scope of this study.
In the future studies we are planning to use more standardised tests and to answer the above questions.

Conclusion: SD is always an important threat in aviation. But the problems we are usually dealing with might not be the whole iceberg. We also have to bring to light the negative effects after SD, the time needed to recover completely and useful countermeasures if possible.